Focal Plane Array Shutter Mechanism

of the JWST NIRSpec Detector System

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Outline

- Requirements
- Chamber location
- Shutter system design
- Motor specs
- Dry lubrication
- Control system
- Environmental cryogenic function testing
- Test results

- Acronyms
  - FPA- Focal Plane Assembly
  - SCA- Sensor Chip Assembly
  - JWST – James Webb Space Telescope
  - NIRSpec – Near Infrared Spectrum

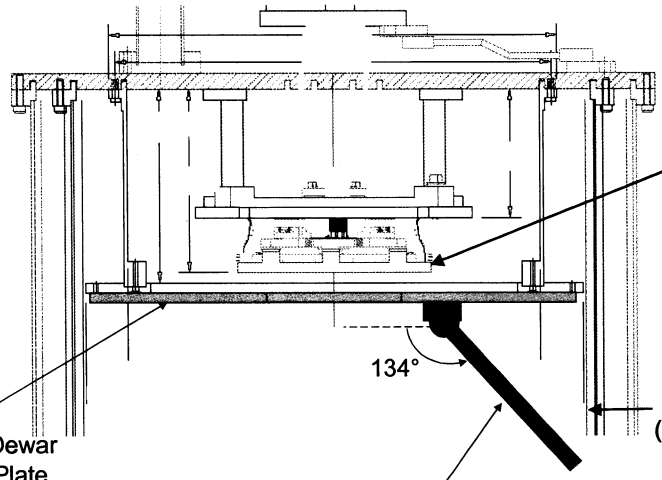
Derived Requirements

- Light baffle mechanism for ground testing for NIRSpec FPA
- 1 degree of freedom operation
- Operate in vacuum (10^{-6} Torr) – mechanism not required to hold vacuum
- Open or close shutter in about one minute
- Operate through several thousand cycles over life
- Fit within "Experimental Shell" diameter ∅302 mm (∅11.9") envelope and on ∅279mm (∅11.0") plate
- Keep maximum height, at any time during operation, <228.5 mm (9")

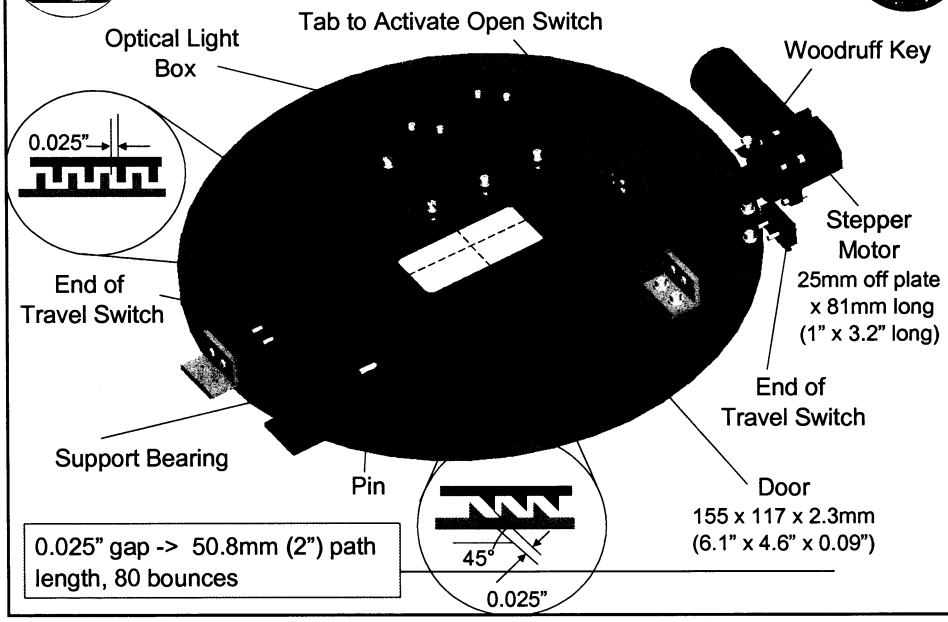
Derived Requirements

- Light tightness
  - Required attenuation = 1 E4
  - Path length designed for specified gap distance
  - Door rotation >90°
- Temperature
  - Operating: -253°C to 27°C (20K to 300K)
- Operate in any direction 1g field
  - Hold position with power off in any direction 1g field

Cryogenic Dewar Interface

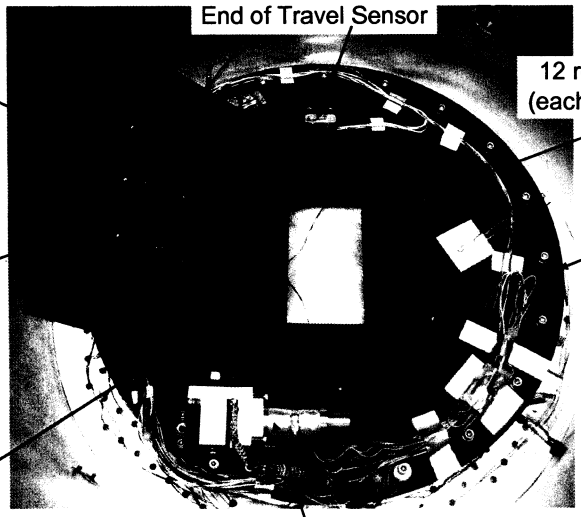


Exploded View

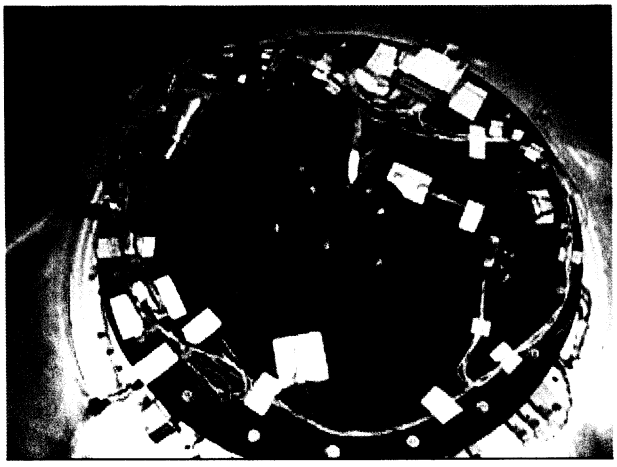


0.025" gap -> 50.8mm (2") path length, 80 bounces

Shutter in Open Configuration



Shutter in Motion



Stepper Motor

- Requires 0.0107 kg m^2 (0.155 oz. in^2) to move door
  - Includes inertia of door and light box
- Requires 0.095 N m (0.84 in. lb) of detent torque (3.2x margin)

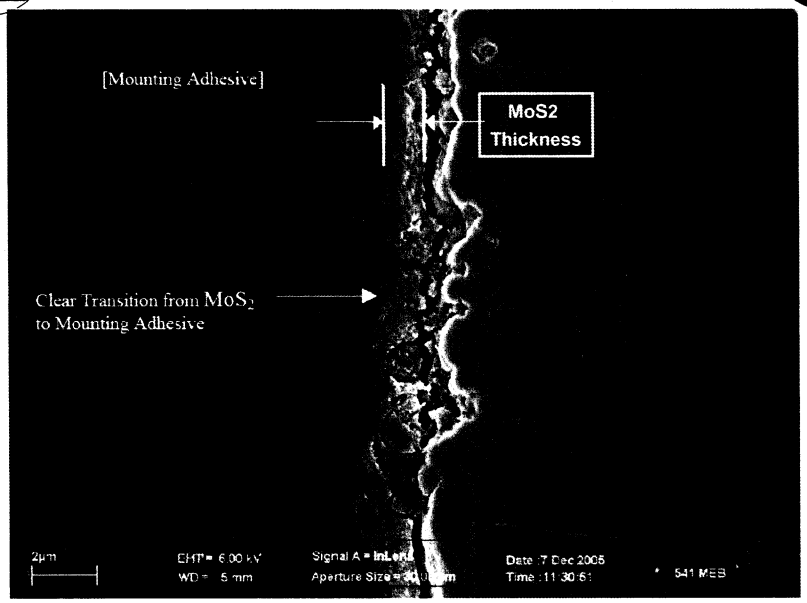
- Stepper Motor Requirements
  - 2 phase
  - 186.7 gear ratio
  - 30 degrees/step
  - Right angle gear head
  - Dry lubrication

0.16° per step resolution at output

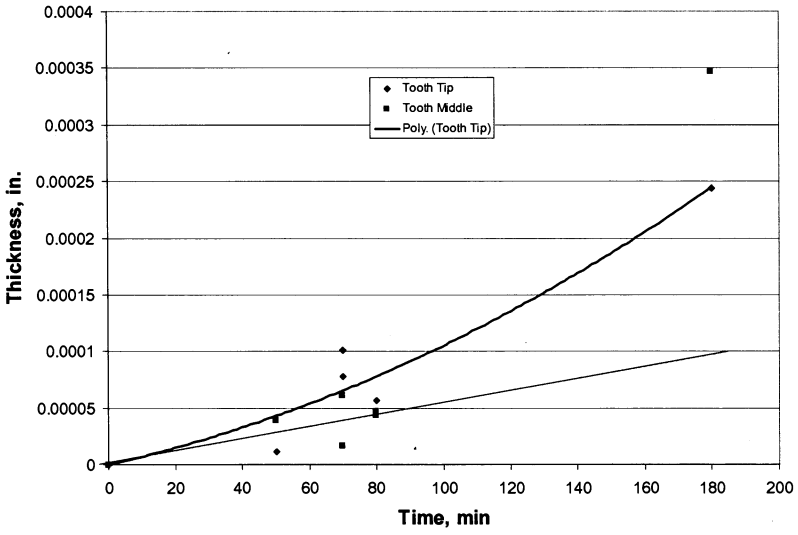
Dry Plating Process for Stepper Motor

- Actuator bearings and gear train parts are lubed with Molybdenum Di-Sulfide
- 22 parts per motor
- We required 0.0001" thick coating
  - Thickness required was determined by maximum thickness allowed due to motor part tolerancing
- Contamination not an issue as motor is contained within a closed volume

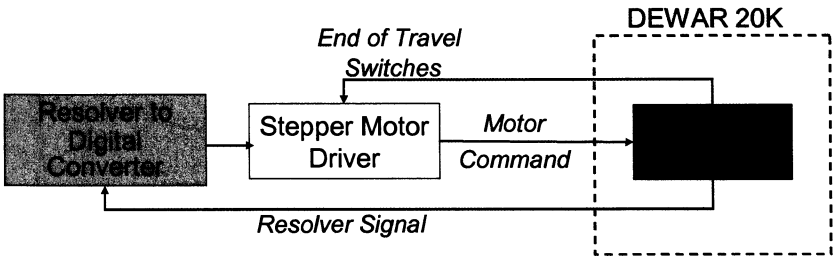
Lubricant Thickness Measurement Along Gear Tooth



MoS2 Coating Thickness vs. Time

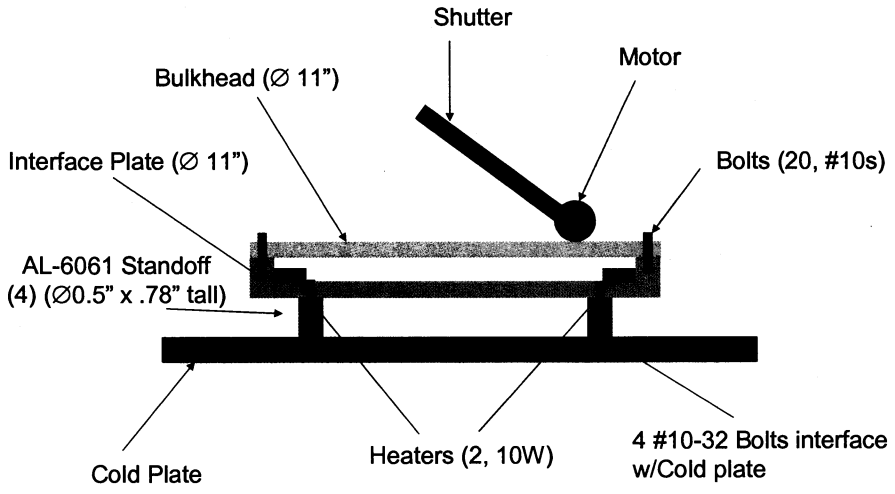


Electrical System & Control

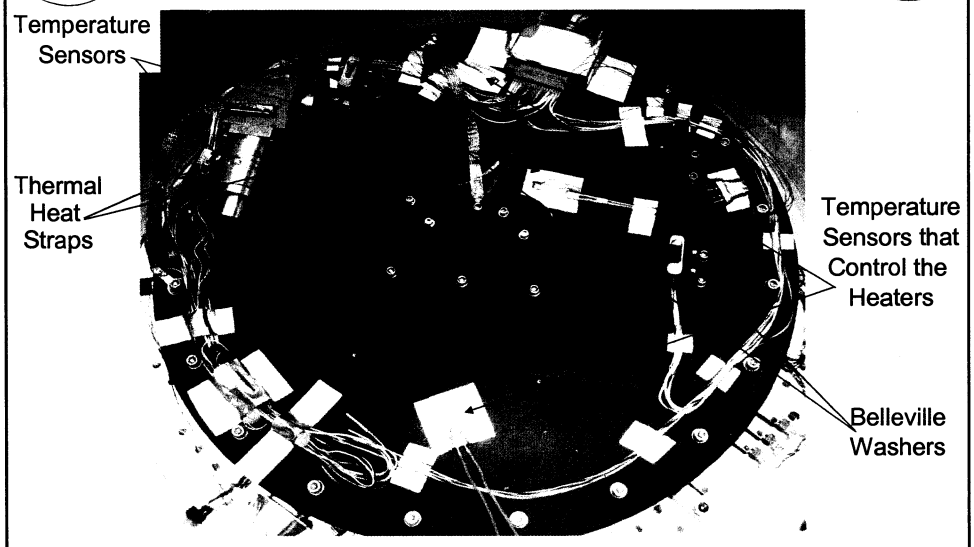


- National Instrument (NI) ESP 300 series stepper controller (3 amp/axis)
- Used resolver and both switches for feedback and control
- Constant current source to motor

Environmental Verification Test Set-up – Side View



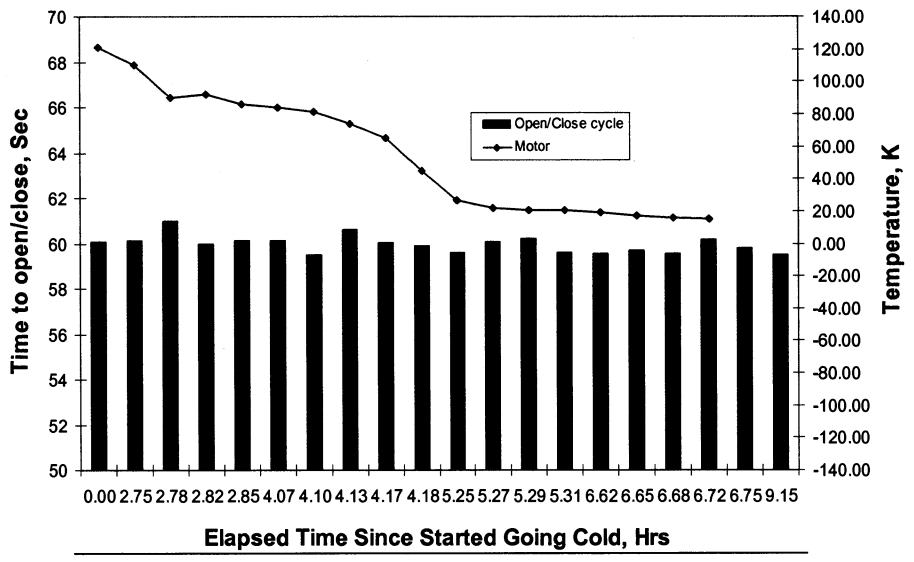
Environmental Test Set-up - Top View



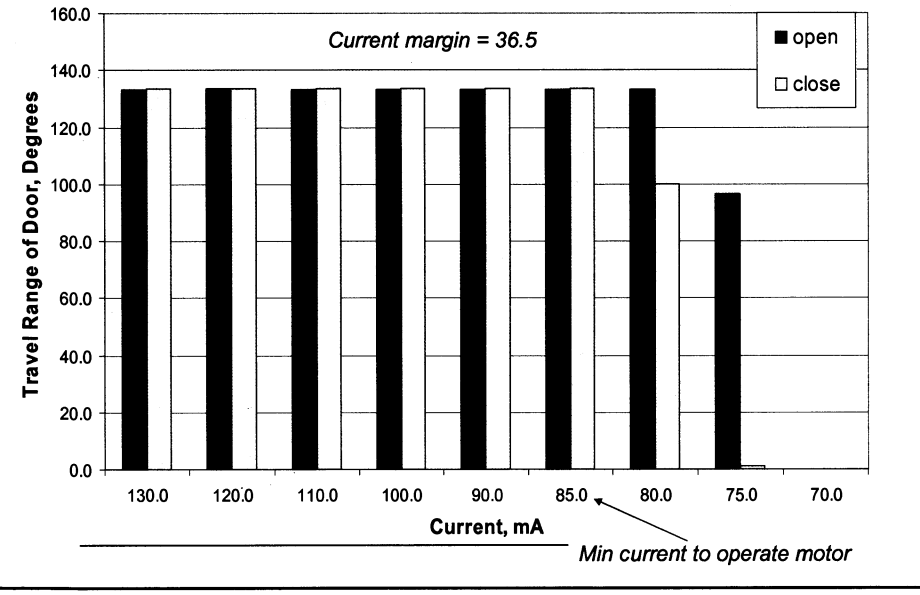
Environmental Test Set-up

- Radial support bearing already dry lubricated by a cage that wears away and provides lubricant
  - Bearing mount made of AL-6061. Calculations performed to ensure CTE mismatch would not affect bearing performance
- Cryogenic compatible end-of-travel sensors purchased
  - Were designed by manufacturer for cryogenic environment but were not previously tested
  - Tested in house by slowing introducing into liquid Nitrogen

Motor Temperature and Shutter Cycle Times vs. Temp



Range Traveled vs. Current at 20K



Lessons Learned - Cryogenic Testing

- Verify all solder connections so ensure connections will not separate when reach cryogenic temperatures
- Check and re-check all electrical connections before buttoning up the chamber
- Use Belleville washers to keep interfaces tight through thermal changes

- Light tightness will be tested when integrated into project's cryogenic dewar with the detectors